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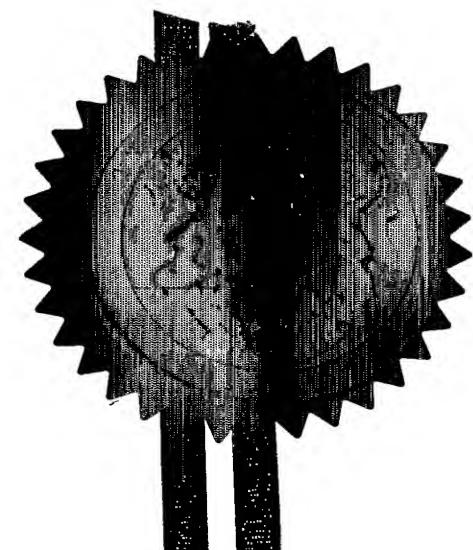
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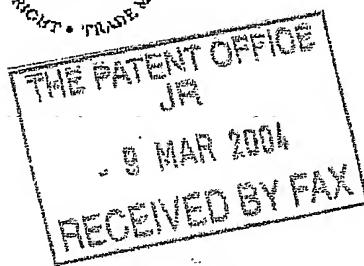
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1. Your reference 15830 TpCm

2. Patent application number 0405185.0

9 MAR 2004

3. Full name, address and postcode of the or of
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Patents ADP number (if you know it)

8132247003

If the applicant is a corporate body, give the
country/state of its incorporation

England & Wales

4. Title of the invention Non-Thermal Plasma Reactor

5. Name of your agent (if you have one)

Clare Josephine Talbot-Ponsonby

"Address for service" in the United Kingdom
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Description

10

Claim(s)

1

Abstract

1

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11. Peter Turquand MANSFIELD (on behalf of Accentus plc by virtue of a Power of Attorney dated 18th February 2003)

I/We request the grant of a patent on the basis of this application.

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Date 9th March 2004

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DUPLICATE

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Non-Thermal Plasma Reactor

The present invention relates to a non-thermal plasma reactor comprising filter elements for the removal of particulates including carbonaceous particulates or soot from gases and in particular for the treatment of gaseous media such as exhaust gases from an internal combustion engine. Such products are encountered in the exhausts of internal combustion engines and effluent gases from incineration or other industrial processes, such as from the pharmaceutical, food-processing, paint manufacturing, dye manufacturing, textiles and printing industries. Coal-fired power stations and gas turbines also produce effluent gases which can be treated in this way.

There is a requirement for improved methods of trapping and removing particulates from exhaust gas streams. US patents 5,853,437 and 6,063,150 disclose a system where particulates are trapped on a filter. The filter is then regenerated by heating the filter to burn off the particulates. US 6,517,786 discloses a reactor where a plasma is used to regenerate the filter. One of the main challenges with achieving highly efficient filtration of particulates from gas streams is minimising the associated pressure drop across the filter caused by the build up of particulates, by successfully regenerating the filter, before the filter clogs up. When a filter is incorporated into a non-thermal plasma reactor the plasma may be generated continuously or intermittently when regeneration is required. The combination of a plasma with a substrate (for example, a filter material) that acts as a particulate trap is known.

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US 6,517,786 discloses a non-thermal plasma reactor for the decomposition of pollutants which comprises a porous electrode arranged along the direction of flow of gas entering the reactor. The waste gas treated in the 5 reactor is constrained to pass through the porous electrode which is designed so as to be permeable to gaseous components but acts as a filter for soot particles.

10 Reactors of this type have the potential to provide a significant reduction in the amount of particulate pollutants present in a gaseous medium. However, in practice a reactor of this type suffers from problems with back-pressure primarily due to the low surface area 15 per volume of reactor. In order for the reactor to be able to treat all of the exhaust gas from, for example, a car, the reactor of the type disclosed in US 6,517,786 has to be large in order to provide a high enough surface area of porous electrode. This typically results in 20 reactors which are too large to be of practical use.

The present invention aims to address this problem and seeks to provide a non-thermal plasma reactor which has a higher surface area of filter for a given volume of 25 reactor.

Accordingly the present invention provides a non-thermal plasma reactor for the treatment of a gaseous medium comprising 30 a plurality of double-sided filter elements in a stack, the elements being connectable alternately to high voltage and earth, and provided with a dielectric barrier between successive filter elements 35 wherein the gaseous medium is constrained to flow into the filter elements.

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The reactor comprises a plurality of filter elements such as two, three, four, five or more filter elements. Preferably the reactor comprises a multiplicity of filter 5 elements such as ten, fifteen, twenty, thirty or more filter elements. The number of filter elements required in a particular reactor will vary depending on the size of the elements, the space restraints on the size of the reactor, the frequency of regeneration of the filters and 10 type of gaseous medium to be treated.

The filter elements are double-sided so as to maximise the surface area of filter in the plasma volume of the reactor. The reactor is typically arranged so 15 that the plasma forms over as large a proportion of the filter area as possible. In one embodiment, the filters at either end of the stack are single-sided and the outer faces of these filters are solid as these faces of the filter elements will not be remediated by plasma.

20 The filter elements comprise a conducting material. The filter elements comprise a filter material which traps particulates but is permeable to gas. Typically, as large a proportion as possible of the filter element is 25 made of the filter material. However, parts of the filter element may be solid in order to provide any necessary stiffness to the element as a whole. The filter element may comprise woven metal filter cloth, metal fibres, sintered metal fibre material or sintered metal powder 30 material. One example of woven metal filter cloth is that made by G Bopp & Co. Examples of sintered metal fibre materials are those obtainable from Porvair Filtration Group Limited - Microfiltrex (Fareham, UK) and Bekhaert (Belgium) made of stainless steel, Monel®, Inconel®, 35 Hastelloy® and Fecralloy®. Stainless steel discs made by sintering powder are available from Martin Kurz & Co Inc

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sold under the name Dynapore™ SPM™ and from Porvair Filtration Group Limited - Microfiltrex. Stainless steel is in general a preferred metal for the filter. Hastelloy® and Fecralloy® are particularly preferred 5 materials as well. Filters such as those described in WO 98/52671 are suitable for use in the present invention.

In a preferred embodiment the filter elements are hollow.

10 The filter elements are typically substantially flat. In a preferred embodiment, the filters are annular, preferably the filters are flat and annular. In another embodiment, the filters are rectangular, square, 15 quadrilateral or another polygon such as a pentagon or hexagon.

The filter elements are attached to the structure of the reactor in such a way that the space inside each 20 filter element communicates only with a space that is outside the reactor. In this way gas that passes into the space inside the filter element can leave the reactor.

For example, where the filter elements are annular 25 in shape, the outer can of the reactor is typically cylindrical. Gaseous medium enters the reactor and flows into the filter element. The filter elements may be connected together such that the space inside each filter element communicates with a cylindrical chamber in the 30 centre of the reactor which is divided from the reactor space. Thus the gaseous medium must flow into the filter elements in order to leave the reactor through the central cylindrical chamber.

35 Where the filter elements are in the form of square, rectangular or other polygonal plates, the elements may

- 5 -

all be connected to one wall of the reactor such that gaseous medium flowing into the reactor space leaves the reactor through that wall of the reactor.

5 The dielectric barrier is a layer of material arranged to provide for a non-thermal plasma of the type referred to as a dielectric barrier type discharge, when an electrical power supply is connected to the filter elements to apply an electrical potential across the
10 space between adjacent filter elements. The dielectric material may be a ceramic material such as alumina or silica or any other ceramic material. Quartz, glass, glass-ceramic and a micaceous glass such as MICATHERM™ are also possible materials.

15 Typically the top and bottom filter elements in the stack are connected to earth.

* In one embodiment, the space between the filter
20 elements is empty. The gaseous medium passes though the space but there is no filling material or catalytic material in the space between the electrodes for it to pass through or over.

25 In another embodiment some or all of the space between the filter elements is filled by a filling material. The filling material is any material which improves the performance of the reactor. It must be able to withstand the temperatures at which the reactor is
30 operating. The filling material is a dielectric material. Suitable materials include ceramic materials such as, but not exclusively, oxides for example aluminas, titanias, silicas, zirconia, glasses, glass ceramics, mixed oxides, complex oxides and metal doped oxides. An example of the
35 latter is silver-doped alumina. The filling can be in the form of spheres, pellets, extrudates, fibres, blanket,

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felt, sheets, wafers, frits, coils, foams, graded foams, membrane, ceramic honeycomb monolith or granules.

The filling material may act as a further filter material, or as a support for a catalyst, or as a catalyst itself or a mixture thereof. Combinations of different catalysts can be used. Vanadates such as metavanadates and pyrovanadates and perovskites are examples of catalysts. Zeolites and metal containing zeolites have a catalytic function. Examples of zeolites are ZSM-5, Y, beta, mordenite and examples of metals that can be used in metal containing zeolites are copper, silver, iron, cobalt. Promoting cations such as cerium and lanthanum can be present in the zeolite composition.

15 A preferred catalyst is silver doped alumina. The catalyst can be in the form of any of the shapes mentioned above for the filling material or as a coating on or contained within a dielectric material. A preferred filling material is a dielectric fibre material such as

20 Saffil (95% by weight alumina; 5% by weight silica) in the form of, for example, a blanket or vacuum formed shape.

The filling material may be coated with a catalyst such as a catalyst for the conversion of NO to NO₂ or NO_x (NO and NO₂) to N₂ in order to improve the processing of noxious exhaust gases in the gaseous medium. The filling material or the filter element may be coated with a catalyst for the conversion of carbon to carbon monoxide and/or carbon dioxide.

The plasma may be generated continuously or intermittently while gaseous medium passes through the reactor. Two reactors may also be connected in parallel and each reactor has gas passed through it in turn. A plasma may then be generated in each reactor either

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intermittently, for example when the gaseous medium for treatment is passing through the other reactor or continuously. Gaseous medium may also be passed through two reactors in parallel simultaneously.

5

The present invention also provides a vehicle such as a car, van, lorry or tank, comprising a reactor according to the present invention. The present invention also provides a ship comprising a reactor according to 10 the present invention. The present invention also provides a power generation unit such as a combustion engine generator e.g. Genset, comprising a reactor according to the present invention.

15

The present invention also provides a method for treating a gaseous medium to remove particulates comprising passing the gaseous medium through a reactor according to the present invention and generating a plasma in the reactor intermittently or continuously.

20

The filter elements in the reactor are regenerated by the plasma. Thus, the plasma is generated for as much time as necessary to regenerate the filter elements.

25

The present invention provides the use of a reactor according to the present invention for the removal of particulates from a gaseous medium. In particular the present invention provides the use of a reactor according to the present invention in a vehicle, power station or other situation where exhaust or effluent gases are 30 produced.

Specific constructions of reactors embodying the invention will now be described by way of example and with reference to the drawings filed herewith, in which:

35

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Figure 1 is a diagrammatic cross-sectional view of a reactor according to the present invention,

Figure 2 is a diagrammatic plan view of a filter 5 as shown in Figure 1,

Figure 3 is a diagrammatic plan view of a filter 3 as shown in Figure 1,

10 Figure 4 is a diagrammatic cross-sectional view of a reactor according to the present invention.

Figure 1 shows a reactor according to a preferred embodiment of the present invention where the double-sided filter elements 3 and 5 are in the form of annular discs. The reactor comprises an outer conducting can 1 which acts as the earth connection 2 for those filter elements 3 which are connected to earth. The reactor comprises twenty-one, thirty-one or more filter elements 20 as necessary of which only five filter elements 3,5 are shown and are connected to earth and high voltage respectively. The filter elements 3 are connected to the outer can of the reactor 2 by tabs 4 at points around the circumference of the filter elements. The intervening filter elements 5 are connected to a high voltage connection 6 by spokes 7 in the centre of the reactor. A dielectric barrier 8 is positioned between each successive filter element 3,5. The dielectric barriers 8, filters 3 and 5 and the annuli 9 of dielectric material 30 together define a central cylindrical space 10 in the centre of the reactor. In another embodiment of the present invention each dielectric barrier 8 and the adjacent annuli 9 may together form a single component (not shown). Gas flowing into the reactor follows the 35 path shown by the arrows in Figure 1. The gas passes around the outer edges of the filter elements 3,5 and the

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dielectric barriers 8 and into the spaces 11 between the filter elements 3,5 and the dielectric barriers 8. Plasma is formed in the space 11 during operation of the reactor. Any particulates in the gas are trapped on the 5 filter surfaces where they can be remediated by the plasma. The gas passes into the space 14 inside the filter elements 3,5. From the space 14 the gas flows into the central space 10 in the centre of the reactor and then leaves the reactor in the direction of the 10 arrows. The structures 12 and 15 (shown schematically) form barriers at either end of the reactor and constrain the gas to flow through the filter elements when passing through the reactor. The high voltage connection 6 is insulated from the reactor can 1 by the insulating 15 structure 13.

The distance between the end 16 of the filters 5 connected to high voltage and the can of the reactor 2 is such that an arc discharge does not form across this 20 space.

Figure 2 shows a plan view of a filter 5 as shown in the reactor of Figure 1. The filter 5 is annular in shape. The filter is connected to a high voltage supply 25 via the spokes 7 and conductor 6 in the centre of the annulus.

Figure 3 shows a plan view of a filter 3 connected to earth as shown in the reactor of Figure 1. The 30 connection to earth is made via tabs 4 which are connected to the outer can of the reactor (not shown).

Figure 4 shows another embodiment of the present invention where the filter elements 21,22 are in the form 35 of flat plates which may be square, rectangular or in the shape of another polygon regular or irregular. Figure 4

- 10 -

shows a cross-section through the reactor. The reactor comprises five filter elements 21,22. Three of the filter elements 21 are connected to the outer can of the reactor 26, which is earthed, by tabs 25 attached to one side of 5 the filter. The remaining two filter elements 22 are connected to a high voltage connection (not shown) through the channel 28. Each filter element is separated from the next by a dielectric barrier 23. The dielectric barriers 23, insulating blocks 27 and the filter elements 10 21,22 make up the side of the reactor shown on the right hand side of the Figure. Gas passing into the reactor follows the path shown by the arrows and passes round the ends of the filter elements and into the space 24 between the filters elements 21,22 and the dielectric barriers 15 23. Plasma forms in the space 24 when the reactor is in use. The gas passes into the filter elements and then leaves the reactor through channel 28.

It will be appreciated that Figures 1 and 4 only 20 show two examples of a reactor according to the present invention. The reactors may contain more or fewer filter elements. The reactors shown in Figures 1 and 4 show the top and bottom filter elements connected to earth. However, the top and/or bottom filter elements may be 25 connected to high voltage if required though this will typically require a large distance between the filter element and the can of the reactor or any adjacent conductor so as to prevent arc discharges from occurring.

30 The distance between the edge of the filter elements 16,22 connected to high voltage and the outer can connected to earth is such that an arc discharge does not occur across the gap. The necessary gap is typically in the range of 1 inch (0.0265 m) per 10 kV of applied 35 voltage in air.

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Claims

1. A non-thermal plasma reactor for the treatment of a gaseous medium comprising
5 a plurality of double-sided filter elements in a stack, the elements being connectable alternately to high voltage and earth, and provided with a dielectric barrier between successive filter elements
10 wherein the gaseous medium is constrained to flow into the filter elements.
2. A reactor according to claim 1 wherein the filter elements are annular.
15
3. A reactor according to claim 1 or 2 wherein the filter elements are hollow.
4. A vehicle, ship or power generation unit comprising
20 a reactor according to any one of claims 1 to 3.
5. A method for treating a gaseous medium to remove particulates comprising passing the gaseous medium through a reactor according to any one of claims 1 to 3
25 and generating a plasma in the reactor intermittently or continuously.
6. Use of a reactor according to any one of claims 1 to 3 for the removal of particulates from a gaseous medium.
30
7. A reactor substantially as hereinbefore described with reference to any one of the drawings.

35 15830 TpCm

C J Talbot-Ponsonby
Chartered Patent Agent
Agent for the Applicant

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Abstract

Non-Thermal Plasma Reactor

5 A non-thermal plasma reactor for the treatment of a
gaseous medium comprising
a plurality of double-sided filter elements in a stack,
the elements being connectable alternately to high
voltage and earth, and
10 provided with a dielectric barrier between successive
filter elements
wherein the gaseous medium is constrained to flow into
the filter elements.

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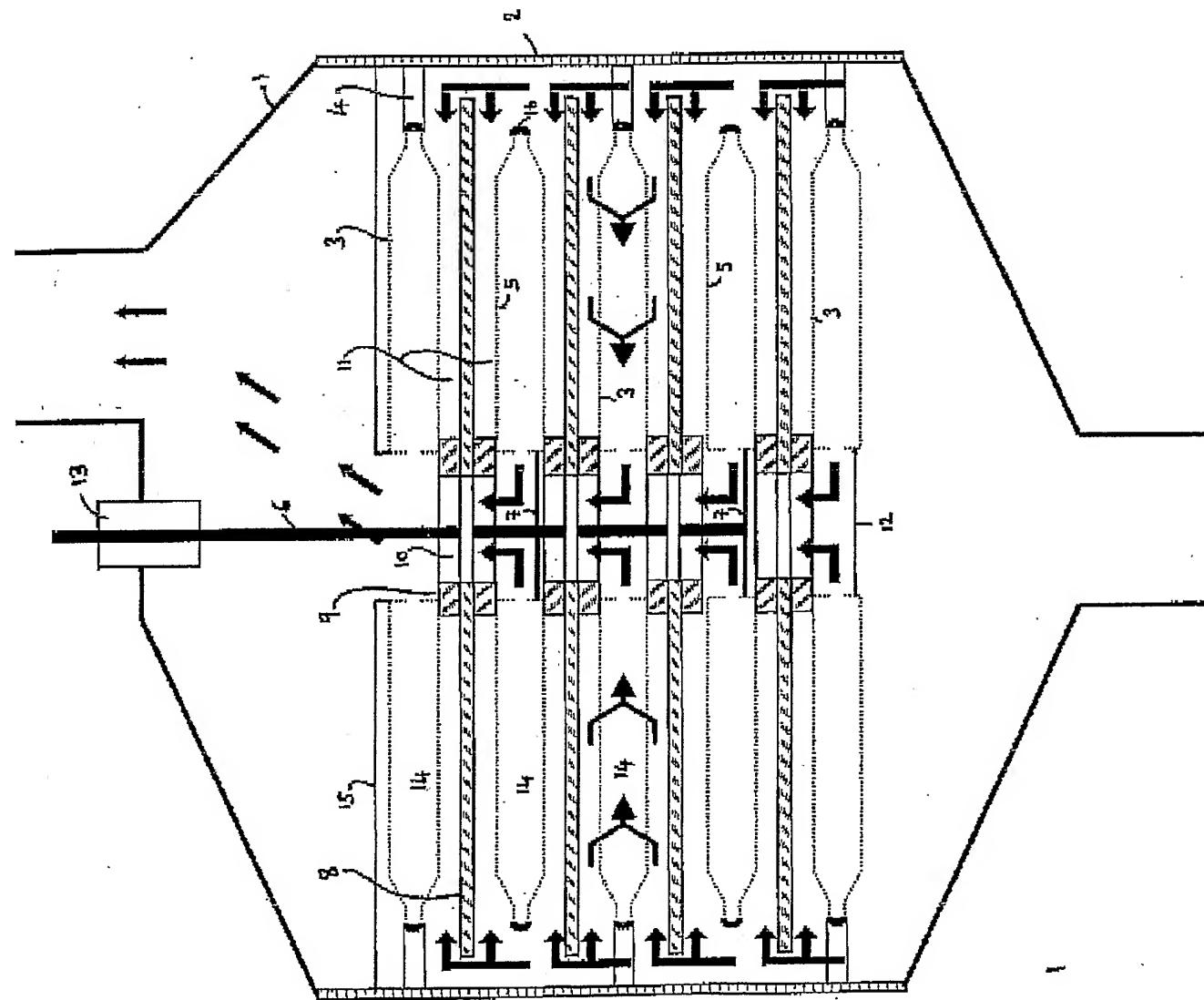


FIGURE 1

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FIGURE 2

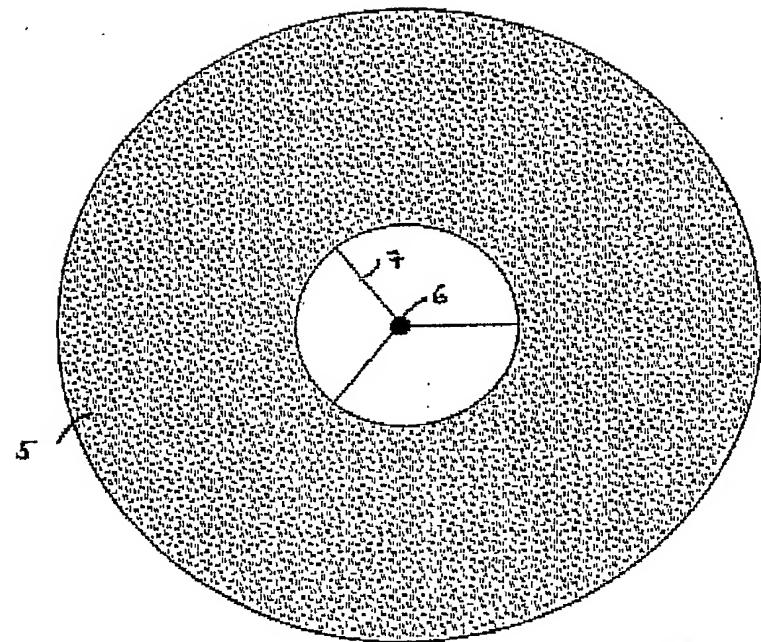
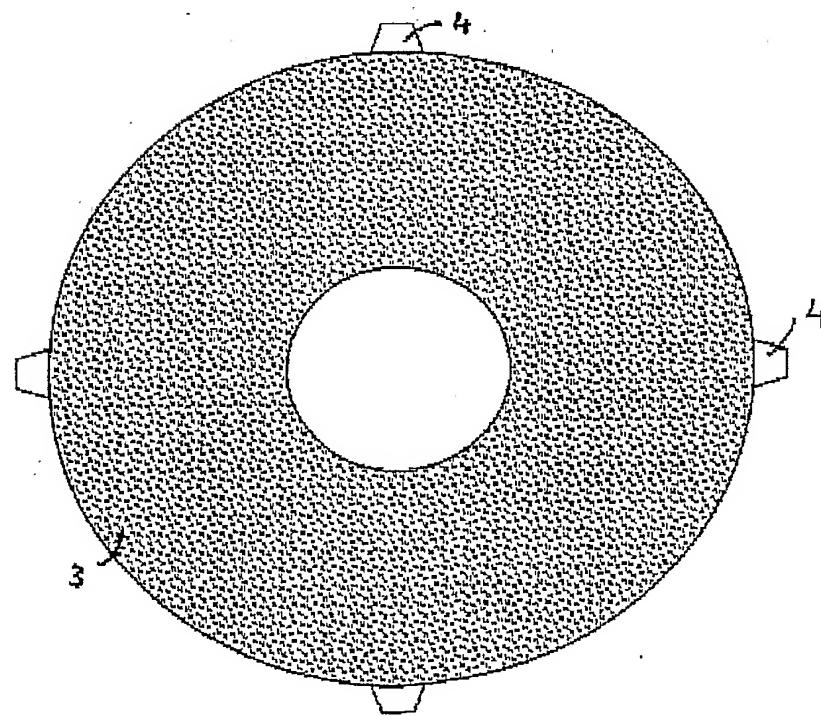


FIGURE 3



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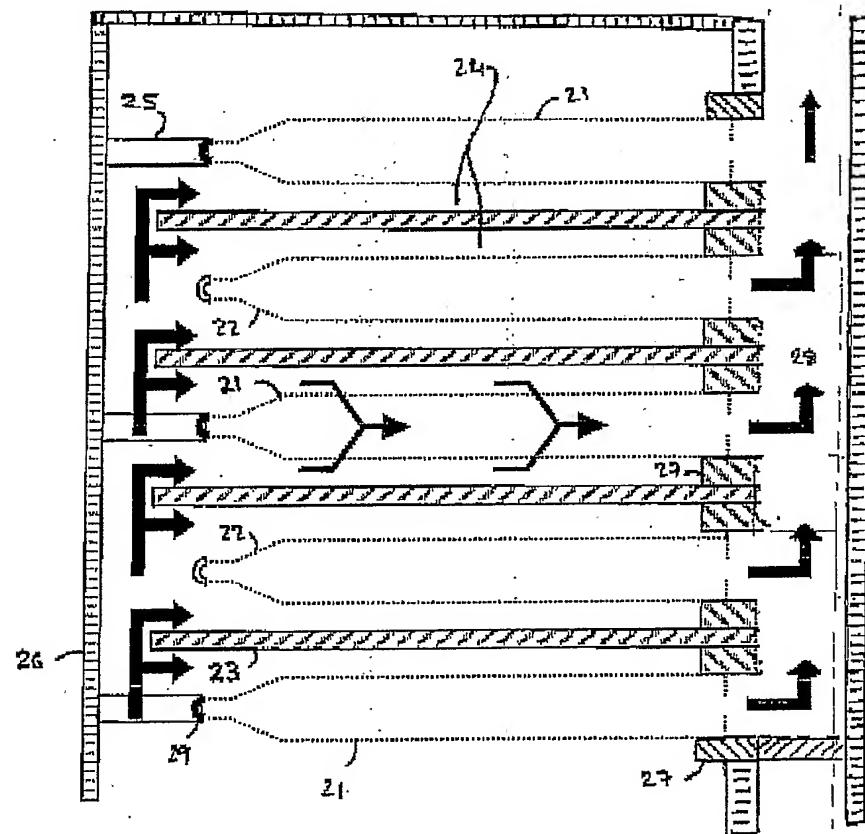


FIGURE 4

